SURFACE ROUGHNESS - "K"

Wind Erosion Equation E=*f*[(I**K**C)LV]

<u>"K" Factor Objectives</u>

Participants will:

- understand the WEQ "K" factor.
- be able to credit "Ridge Roughness" in planning wind erosion control systems.
- be able to credit "Random Roughness" in planning wind erosion control systems.

<u>"K" - Ridge Roughness</u>

Ridge roughness "K" is a measure of the effect of patterns of ridges and furrows created by tillage and planting implements. Ridges absorb and deflect wind energy and trap moving soil particles. It is expressed as a value ranging from 0.5 to 1.0.

Ridge roughness is a pattern of oriented ridges and furrows created by field operations that is predictable in terms of height, spacing, and durability.

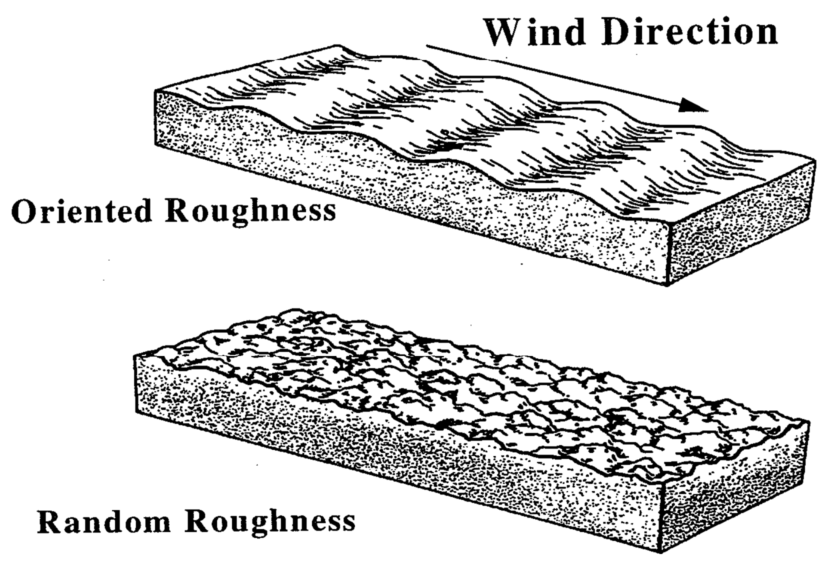


Figure 6. Comparison of Roughness Types

Ridges absorb and deflect wind energy as well as trap moving soil particles. The trapped soil particles flow over the ridge, to the zone of accumulation. Some soil particles flow back and downward from the ridge, go into suspension or begin the saltation process (see Figure 7).

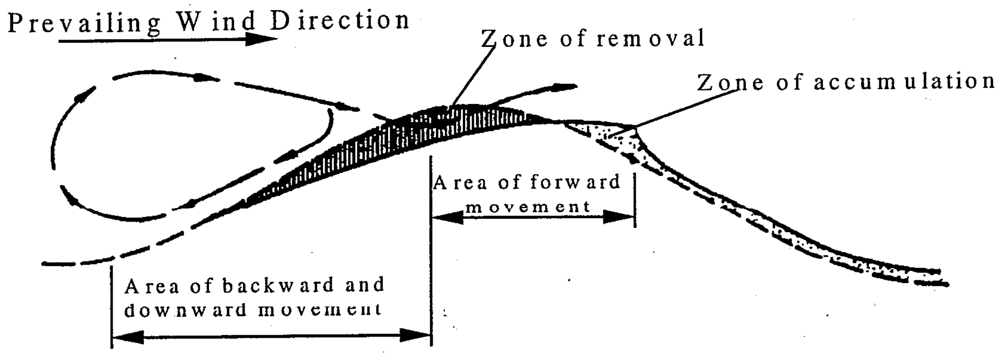


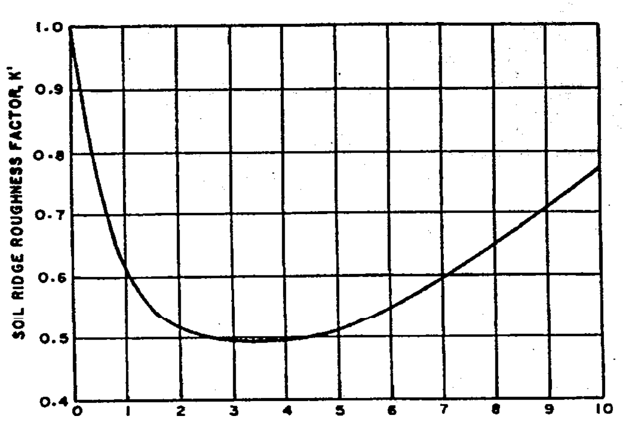
Figure 7. Soil Movement on Ridges

Information Needed to Determine the "K" Factor for Ridge Roughness

- Angle of Deviation
  * Prevailing wind erosion direction
  * Ridge-furrow direction
- Ridge Height
- Ridge Spacing

The "K" factor is based on a standard ridge height to ridge spacing ratio of 1:4. Calibrations of wind tunnel studies led to the development of this curve that relates ridge-furrow roughness to the "K" factor.

This curve is the basis for the "K" factor tables found in Exhibit 502.62 in the National Agronomy Manual and in the Field Office Technical Guide.



$$K_r = \frac{4h^2}{s}$$

where:

h = ridge height in inches

s = ridge spacing (inches) measured in the wind erosion direction

Figure 8. Graph to determine soil ridge roughness factor <u>K</u> from soil ridge roughness <u>Kr.</u>

K factor tables have been developed for typical ridge heights and spacings.

TABLE 8.

Example K Factor Table

Angle of Deviation = 0°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.5	0.5	0.6							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.7					
20	0.9	0.6	0.5	0.5	0.5	0.6	0.8	0.8			
24	0.9	0.7	0.5	0.5	0.5	0.5	0.7	0.8	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
40	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8

Prevailing Wind Erosion Direction

The prevailing wind erosion direction (PWED) is the direction from which the greatest amount of winds exceeding threshold velocity (13 mph at 1 foot above the soil surface or 18 mph at 30 feet of height) occur. Erosive winds may blow in either direction along this wind directional line but are dominated by winds from the indicated direction.

The prevailing wind erosion direction is based on wind direction and wind speed at official weather stations. A weather station should be assigned to represent each geographic location.

Angle of Deviation

The angle of deviation is the angle between the prevailing wind erosion direction (PWED) and a line perpendicular to the ridge-furrow direction.

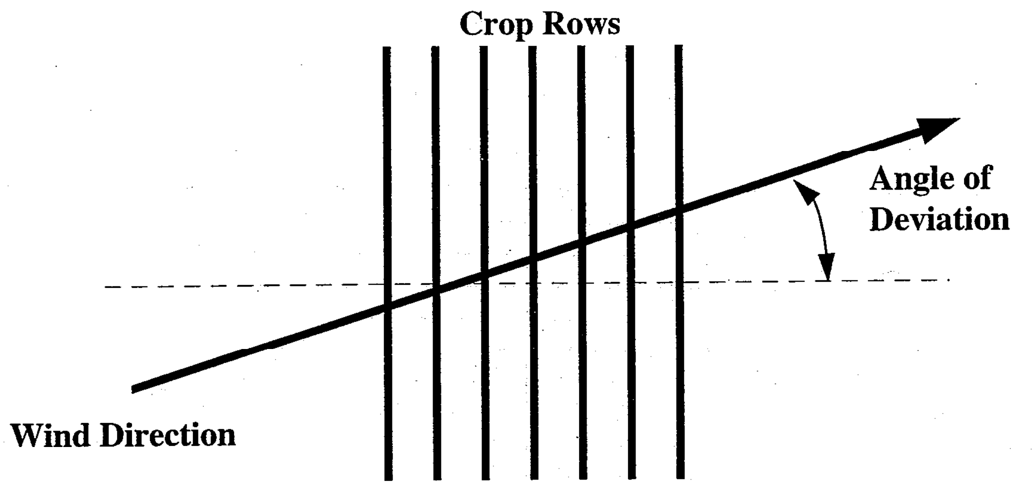


Figure 9. Illustration of Angle of Deviation

The wind direction diagram (as in Figure 10) can be used to determine the angle of deviation when computing the K factor.

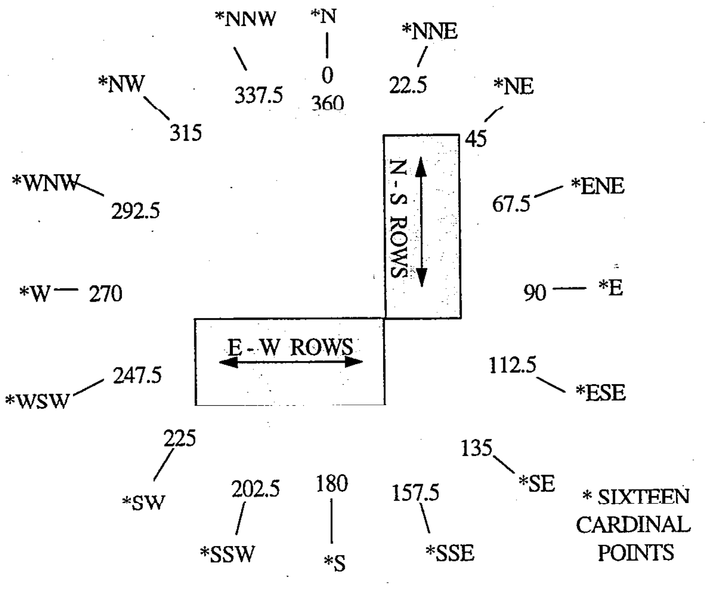


Figure 10. Wind Directions

Figure 11 shows that the effect of ridges varies as the wind direction changes. When an erosive wind is perpendicular (angle of deviation is 0°) to ridges 4 inches high and 30 inches apart, the I factor of the soil is 134, and assuming no random roughness, "K" is 0.5. When the erosive wind is blowing parallel to those same ridges, "K" is 1.0 (angle of deviation = 90 degrees). Since erosive winds seldom blow exactly perpendicular nor exactly parallel to ridges, the angle of deviation is used to adjust the ridge spacing to the distance along the prevailing wind direction.

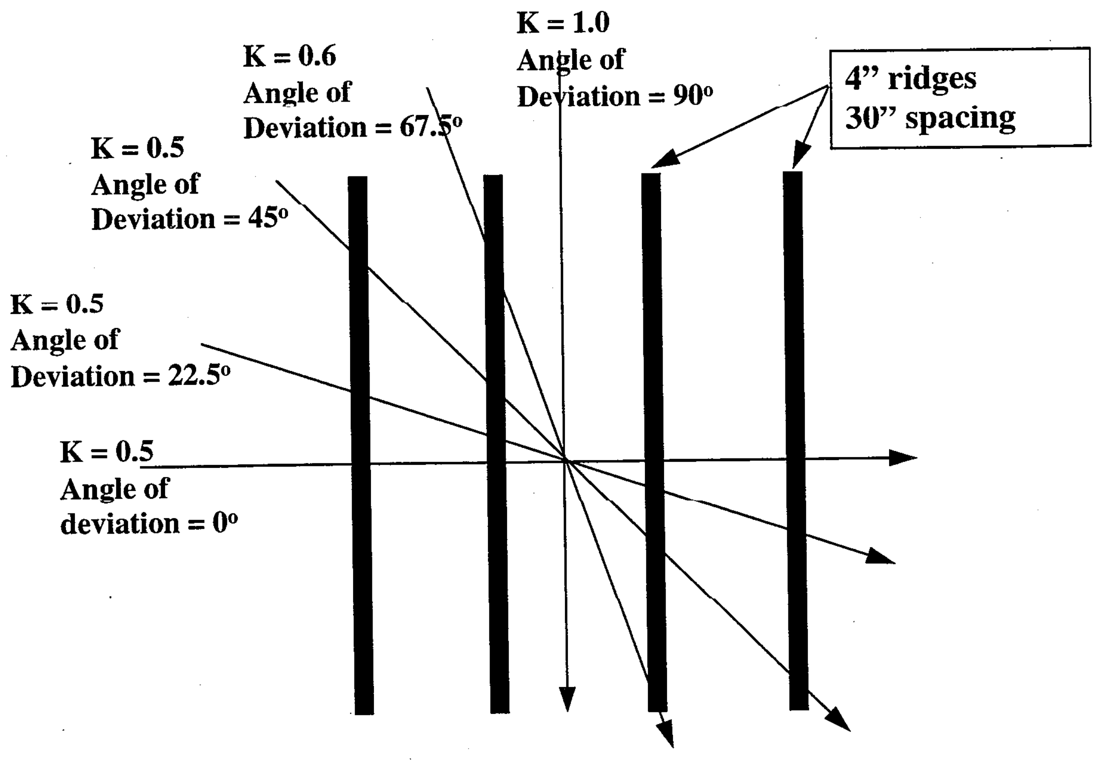


Figure 11. Effect of Angle of Deviation on K Factor Value

Table 9 gives you a quick reference to find the angle of deviation of the prevailing wind when ridges are oriented either north-south or east-west.

TABLE 9.

Angle of Deviation for E-W or N-S Rows with Varying Prevailing Wind Erosion Directions

Prevailing Wind Erosion Direction, in Degrees	Angle of Deviation, Rows Planted E - W	Angle of Deviation, Rows Planted N - S
22.5	22.5	67.5
45	45	45
67.5	67.5	22.5
90	90	0
112.5	67.5	22.5
135	45	45
157.5	22.5	67.5
180	0	90
202.5	22.5	67.5
225	45	45
247.5	67.5	22.5
270	90	0
292.5	67.5	22.5
315	45	45
337	22.5	67.5
360	0	90

"K" Factor Tables

The "K" factor tables provide a quick look up reference once the angle of deviation, ridge height, and ridge spacing are determined.

Table 10.

K Factor Values

Angle of Deviation = 0°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.5	0.5	0.6							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.7					
20	0.9	0.6	0.5	0.5	0.5	0.6	0.8	0.8			
24	0.9	0.7	0.5	0.5	0.5	0.5	0.7	0.8	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
40	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8

Table 11.

K Factor Values

Angle of Deviation = 22.5°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.6	0.5	0.5							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.6					
20	0.9	0.7	0.5	0.5	0.5	0.6	0.7	0.8			
24	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.8	
40	1.0	0.8	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8

Table 12.

K Factor Values

Angle of Deviation = 45°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.8	0.5	0.5								
10	0.8	0.6	0.5	0.5							
14	0.9	0.6	0.5	0.5	0.5						
18	0.9	0.7	0.6	0.5	0.5	0.5					
20	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7			
24	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.8		
30	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.6		
36	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.6	
38	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.6	
40	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.7

Table 13.

K Factor Values

Angle of Deviation = 67.5°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.9	0.6	0.5								
10	0.9	0.7	0.6	0.5							
14	0.9	0.8	0.6	0.6	0.5						
18	1.0	0.8	0.7	0.6	0.5	0.5					
20	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5			
24	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5		
30	1.0	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5		
36	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	
38	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	
40	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5

Table 14.

K Factor Values

Angle of Deviation = 90°

The soil ridge roughness “K” is always 1.0 when the prevailing wind erosion direction is parallel to the ridge pattern (angle of deviation = 90°).

"K" - Random Roughness

Random roughness is the non-oriented surface roughness that is sometimes referred to as cloddiness. It is usually created by the action of tillage implements. Random roughness is defined as the standard deviation of elevation from a plane across a tilled area, after oriented roughness is accounted for. Random roughness values are represented as the *standard deviation* of roughness heights.

Random roughness (inches) from the machine operations database in RUSLE can be used to determine random roughness values. These values are given in Table 15. It is important to remember that these RUSLE random roughness values were determined from medium textured soils tilled at optimum moisture conditions for creating roughness. Under most circumstances, random roughness should be determined by comparing a field surface to the random roughness (standard deviation) photos in Agriculture Handbook 703, *Predicting Soil Erosion By Water: A Guide To Conservation Planning With The Revised Universal Soil Loss Equation (RUSLE).* These photos are provided at the end of this subpart.

The major effects of random roughness on wind erosion are to raise the threshold wind speed at which erosion begins, and to provide some sheltered area among clods where moving soil can be trapped. Hence, as random roughness values increase, the K value decreases.

Random roughness is subject to much faster degradation by rain or wind erosion than large tillage ridges. Therefore, the WEQ management period during which random roughness is effective may be of short duration.

The WEQ "K_{rr}" factor for Random Roughness has been developed for various levels of "I" values and surface random roughness (see Figure 12).

When both random roughness and ridge roughness are present in the field, they are complementary. Random roughness, particularly in furrows, reduces wind erosion which occurs along wind directions parallel to the ridges.

When both are present, the K factors for ridge roughness and random roughness are to be multiplied together to obtain the total roughness K factor value. Until the complete K factor routine is changed in the NRCS National Agronomy Manual, a total roughness K factor value of 0.5 will be the lowest allowed for estimating wind erosion.

Use of the Random Roughness Factor in New Mexico

An erosion modification procedure, adopted by NRCS in New Mexico in 1987, addressed the benefits of random roughness and other factors in reducing wind erosion. The NM NRCS modification procedure was based on the technical judgment of NM NRCS personnel. On irrigated cropland only, the New Mexico NRCS modification procedure provides more acceptable erosion predictions than the recent ARS irrigation modifier and random roughness adjustments. The random roughness factor will be applied only to dry cropland according to the procedures in this section. On irrigated fields, the New Mexico modification procedure will be used in place of the random roughness factor and other recent ARS irrigation adjustments until new technology (WEPS) is in place that more accurately estimates wind erosion.

TABLE 15.

RANDOM ROUGHNESS VALUES FOR "CORE" FIELD OPERATIONS[1]

Field Operations	Random Roughness (in)	Field Operations	Random Roughness (in)
Chisel, sweeps	1.2[2]	Fertilizer applicator, anhydrous knife	0.6
Chisel, straight points	1.5	Harrow, spike	0.4
Chisel, twisted shovels	1.9	Harrow, tine	0.4
Cultivator, field	0.7	Lister	0.8
Cultivator, row	0.7	Manure injector	1.5
Cultivator, ridge till	0.7	Moldboard plow	1.9
Disk, one way	1.2	Mulch treader	0.4
Disk, heavy plowing	1.9	Planter, no-till	0.4
Disk, tandem	0.8	Planter, row	0.4
Drill, double disk	0.4	Rodweeder	0.4
Drill, deep furrow	0.5	Rotary hoe	0.4
Drill, no-till	0.4	Vee ripper	1.2
Drill, no-till into sod	0.3		

[1] These values are typical and representative for operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may vary by cropping region, farming practice, soil texture, or other conditions.

[2] These values may be used in WEQ for random roughness. However, the use of the random roughness photos in Agriculture Handbook 703 is preferable.

Random Roughness Photos

Exhibit A at the end of this section displays the random roughness photos from Agriculture Handbook 703.

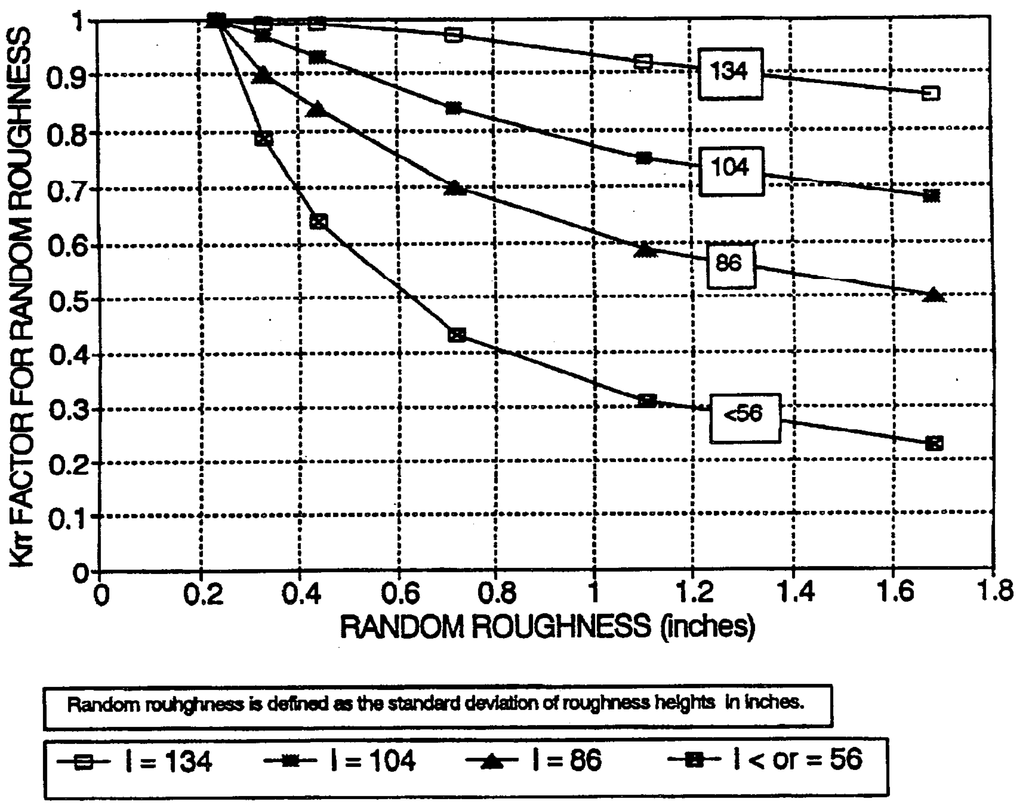


Figure 12. Graph to Determine K_r from Random Roughness and "I" Factor Values

"E" Tables

Tables 16 and 17 illustrate the effect of roughness on predicted soil erosion.

TABLE 16.

E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR C = 90

SURFACE - K = 1.0 I = 134

L UNSHELTERED DISTANCE IN FEET	V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE												
	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
8000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
6000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
4000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
3000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
2000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
1000	115.5	102.4	84.6	67.1	45.5	27.9	15.7	9.0	6.0	2.5	1.3	0.2	
800	114.1	101.0	83.4	66.0	46.7	27.3	15.3	8.7	5.8	2.4	1.2	0.2	
600	108.7	96.1	74.0	62.1	41.7	25.1	13.9	7.8	5.1	2.1	1.0	0.2	
400	103.2	91.0	74.5	58.3	38.8	22.9	12.5	7.0	4.5	1.8	0.9	0.1	
300	98.9	87.1	71.0	55.2	36.5	21.3	11.5	6.3	4.1	1.6	0.8	0.1	
200	90.1	79.0	64.0	49.2	32.0	18.2	9.6	5.1	3.2	1.2	0.4		
150	82.6	72.2	58.1	44.1	28.3	15.6	8.1	4.2	2.6	0.9	0.3		
100	76.0	66.3	52.9	39.8	25.2	13.6	6.9	3.5	2.1	0.7			
80	71.0	61.6	48.9	36.5	22.8	12.0	6.0	3.0	1.8	0.6			
60	62.9	56.0	42.4	31.1	19.1	9.7	4.7	2.2	1.3				
50	57.8	49.9	38.9	28.3	17.1	8.5	4.0	1.9	1.1				
40	54.0	48.4	36.0	25.9	15.5	7.5	3.9	1.6	0.9				
30	47.3	40.4	31.0	22.0	12.9	6.0	2.7	1.2	0.5				
20	38.3	32.9	24.5	16.9	9.6	4.2	1.8	0.6					
10	26.8	22.4	16.5	10.9	5.8	2.3	0.9						

TABLE 17.

E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR C = 90

SURFACE - K = 0.5 I = 134

L UNSHELTERED DISTANCE IN FEET	V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE												
	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
8000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
6000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
4000	58.6	50.6	39.5	28.8	17.4	8.7	4.1	1.9	1.1				
3000	57.5	49.5	38.6	28.1	17.0	8.4	4.0	1.9	1.1				
2000	56.3	48.5	37.7	27.3	16.5	8.1	3.8	1.8	1.0				
1000	49.4	42.7	33.4	23.5	13.9	6.6	3.0	1.3	0.6				
800	48.2	41.2	31.2	22.5	13.2	6.2	2.8	1.2	0.5				
600	44.8	38.2	29.2	20.5	11.9	5.5	2.4	1.1	0.5				
400	39.9	33.9	25.7	17.8	10.1	4.5	1.9	0.8	0.4				
300	36.8	31.2	23.4	16.1	9.0	3.9	1.6	0.6					
200	31.8	26.8	19.9	13.4	7.4	3.0	1.2	0.49					
150	27.5	23.1	16.9	11.2	6.0	2.6	0.9						
100	23.6	19.7	14.3	9.3	4.9	1.8	0.7						
80	21.1	17.5	12.6	8.1	4.2	1.9	0.5						
60	17.2	14.1	10.0	6.2	3.1	1.1							
50	14.8	12.1	8.5	5.2	2.5	0.8							
40	13.1	10.7	7.4	4.5	2.1	0.4							
30	10.1	8.1	5.5	3.2	1.5	0.3							
20	6.3	5.0	3.3	1.8	0.7								
10	2.2	1.6	1.0	0.4									

Rules of Thumb

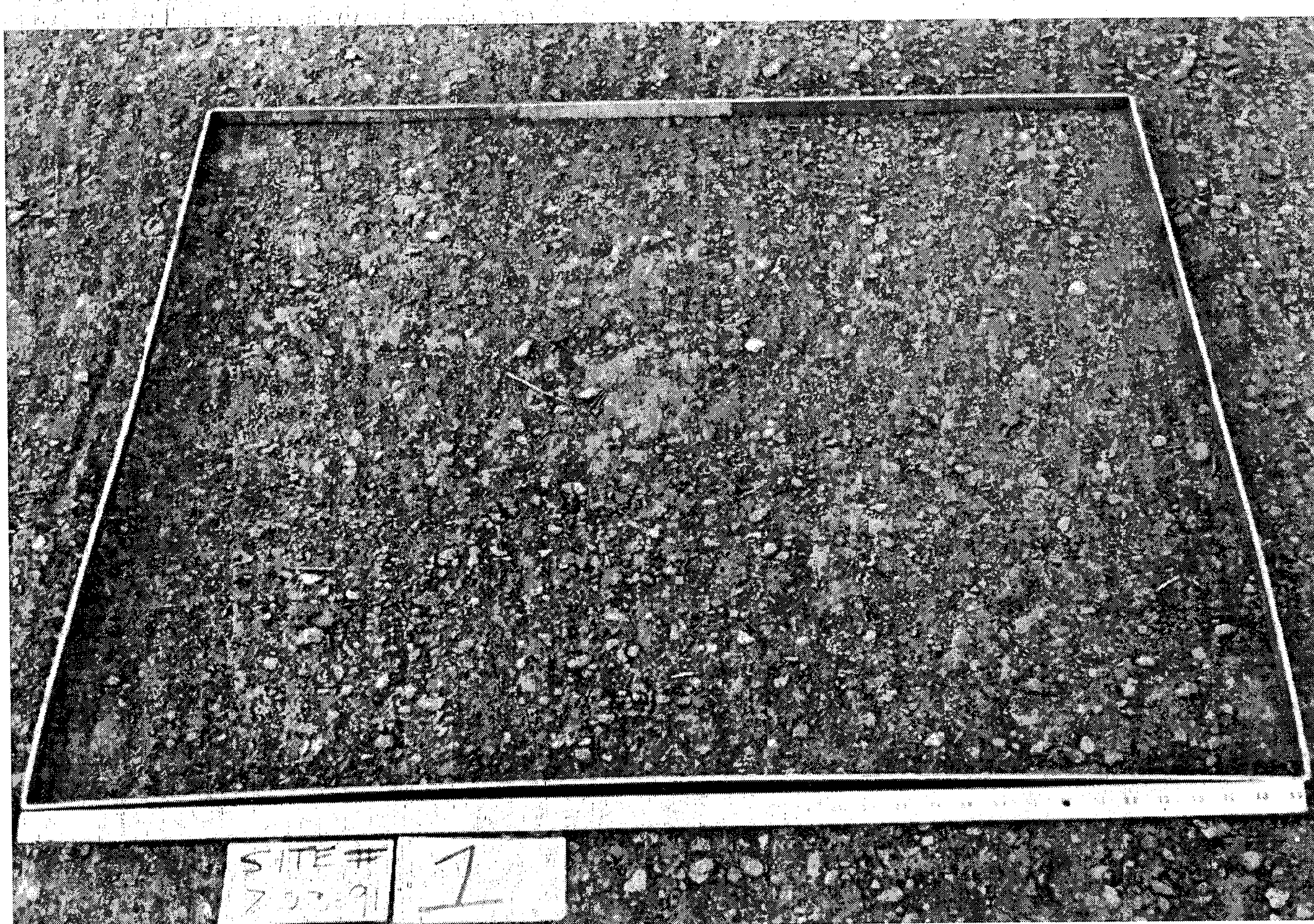
- The angle of deviation value is always from 0 to 90 degrees.
- Ridges in a field have two directions. The second direction of a ridge can be computed by adding 180 degrees to (or subtracting 180 degrees from) the known ridge direction. This applies to the line perpendicular to the ridge direction as well as the ridge direction. For example, the second direction for 45 degrees (opposite cardinal point) is 225 degrees.
- The angle of deviation is computed by relating the prevailing wind erosion direction to the direction of the perpendicular line.
- K factor charts are available for the following angles of deviation:
  * 0
  * 22.5
  * 45
  * 67.5
  * 90

"K" Factor Summary

- Ridges and furrows affect the detachment, transport and deposition of soil particles.
- Ridges are most effective when they are perpendicular to the prevailing wind erosion direction.
- The "K" factor accounts for both oriented roughness and random roughness.
- The "K" factor values for oriented roughness and random roughness are multiplied together to arrive at the final "K" factor value (minimum allowable "K" is 0.5).

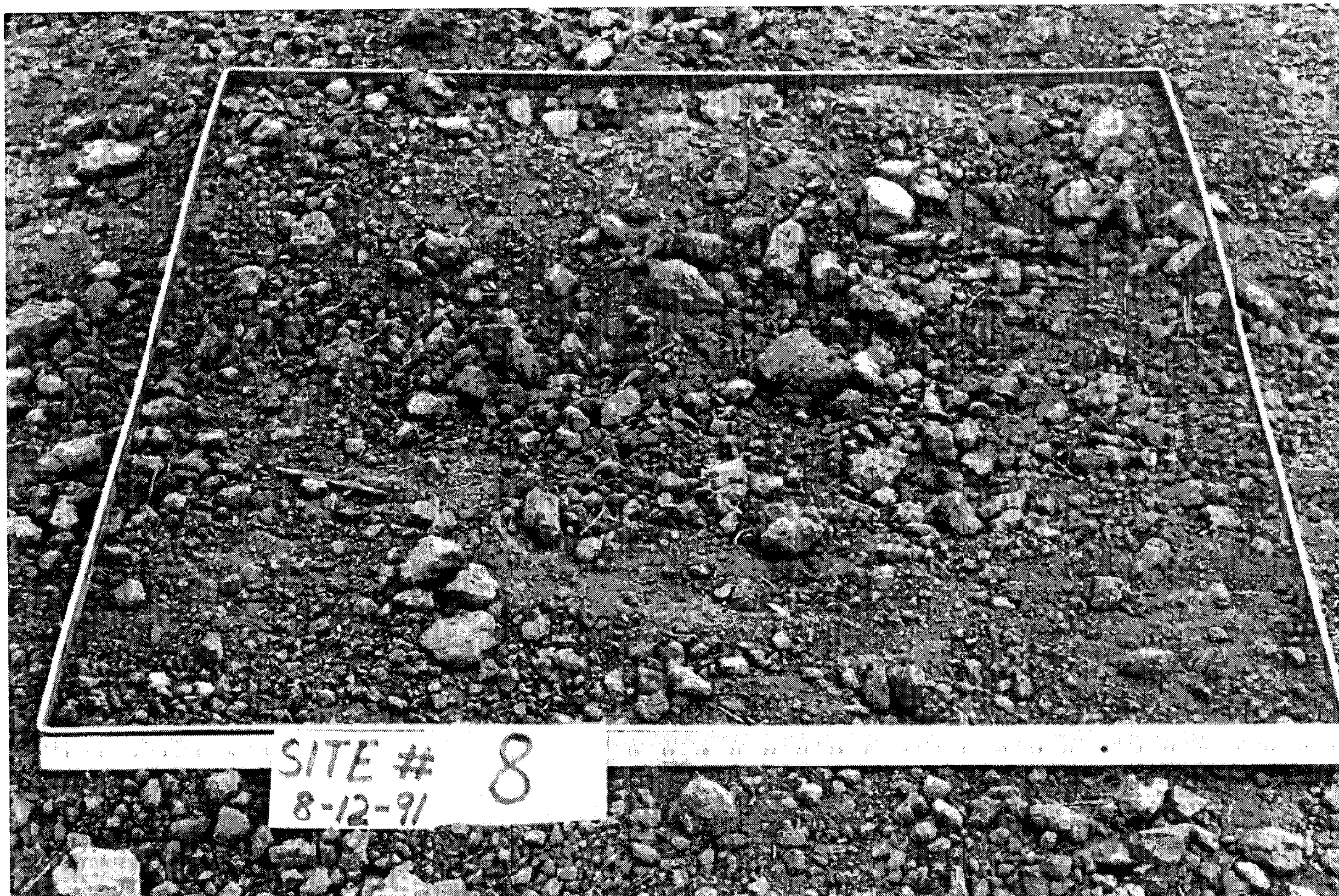
Exhibit A

Random Roughness, R_t, of 0.25 inches



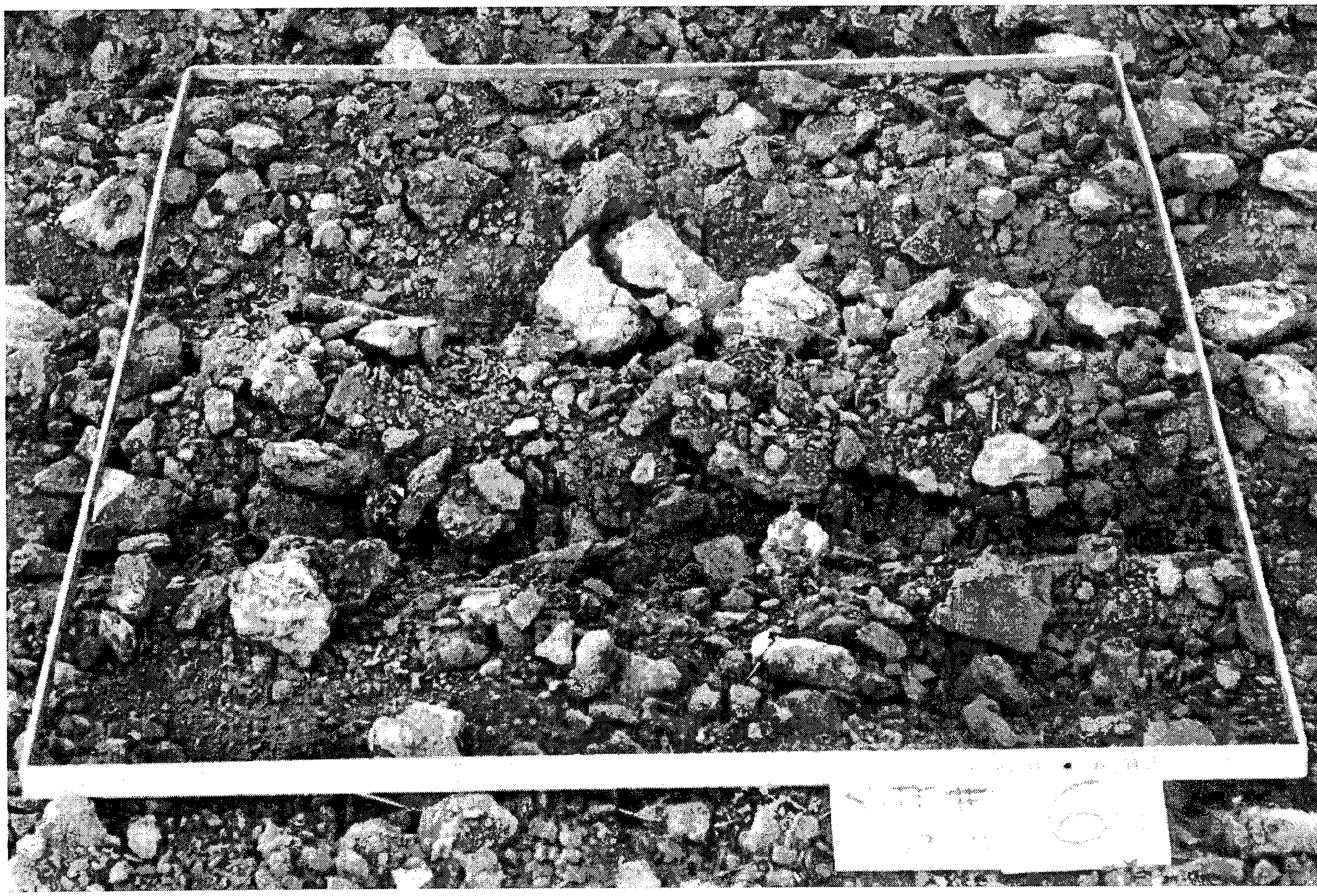
Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 339

Random Roughness, R_t, of 0.40 inches



Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 340

Random Roughness, R_t, of 0.75 inches



Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 342

Random Roughness, R_t, of 0.65 inches

Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 341

Random Roughness, R_t, of 0.85 inches

Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 343

Random Roughness, R_t, of 1.05 inches

Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 344

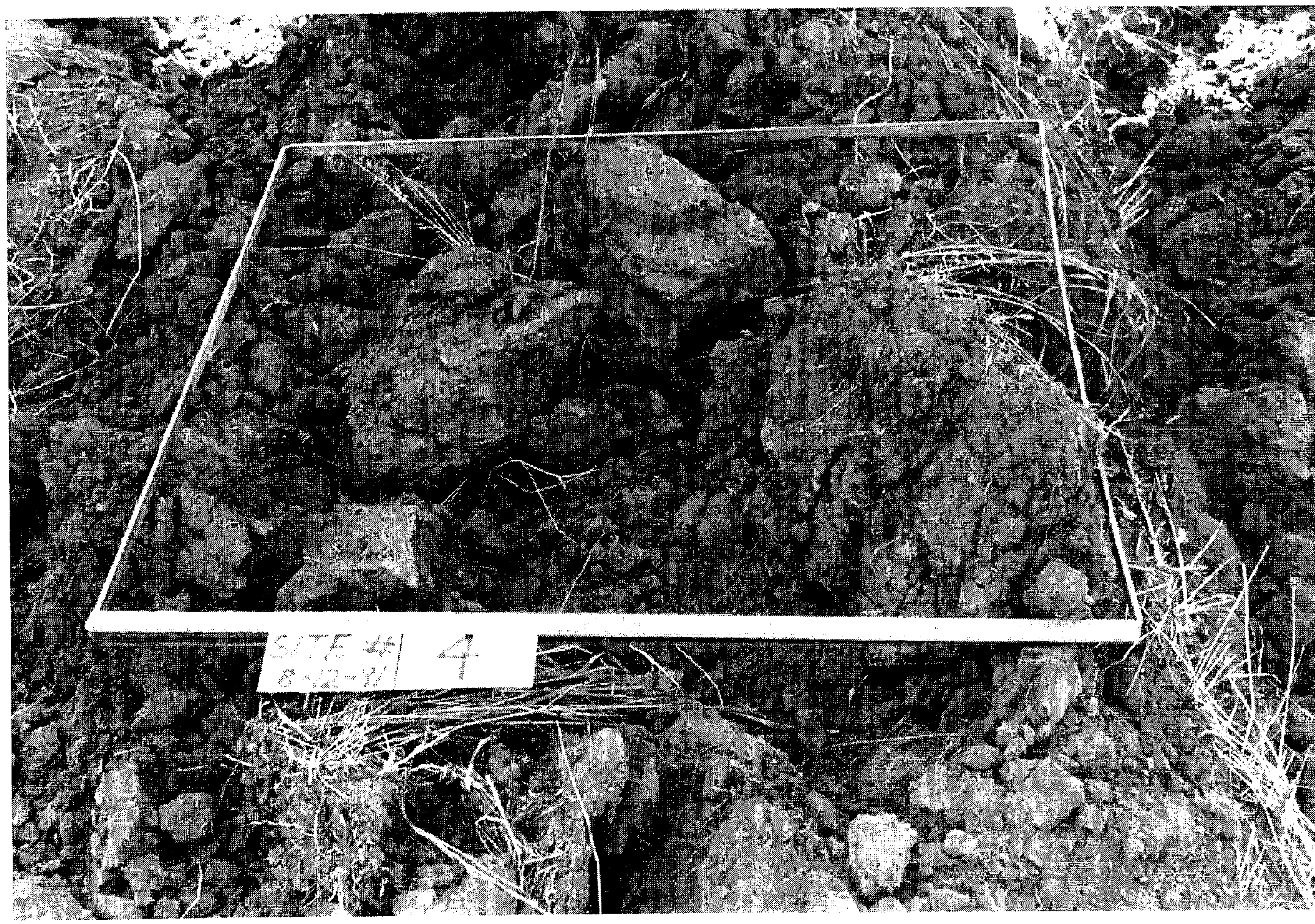
Random Roughness, R_t, of 1.60 inches

Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 345

Random Roughness, R_t, of 1.70 inches

Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 346

Random Roughness, R_t, of 2.15 inches



Source: Agriculture Handbook Number 703, USDA-ARS, *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*, page 347